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# From bench to bedside: The societal orientation of research leaders: The case of biomedical and health research in the Netherlands

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This paper answers five questions about the societal impact of research. Firstly, we examine the opinions of research group leaders about the increased emphasis on societal impact, i.e. does it influence their research agenda, communication with stakeholders, and knowledge dissemination to stakeholders? Furthermore, we investigate the quality of their societal output. We also study whether the societal and scholarly productivity of academic groups are positively or negatively related. In addition, we investigate which managerial and organisational factors (e.g. experience of the principal investigator, group size and funding) influence societal output. Finally, we show for one case (virology) that societal impact is also visible through indirect links. Our study shows that research group leaders have a slightly positive attitude towards the increased emphasis on the societal impact of research. The study also indicates a wide variety of societal-oriented output. Furthermore, the societal and scientific productivity of academic groups are unrelated, suggesting that stimulating social relevance requires specific organisational and contextual interventions.

*Keywords: societal output; research groups; research funding; science communication; incentive structures; science system.*

## 1. Introduction

Academic science is currently shaped by pressure towards academic excellence and by aspirations towards knowledge transfer and research activities beyond academia. Over the years, discussions about the societal value of academic science have become more extensive—and research funding agencies increasingly ask about the explicit societal relevance of proposed research. Within science policy studies, a series of concepts has been introduced to theorise these changes in the science-society relationship: ‘mode 2 knowledge production’ (Gibbons et al. 1994), ‘triple helix of university–government–industry relations’ (Etzkowitz and Leydesdorff 1995), ‘knowledge society’ (Stehr 1994), ‘Pasteur’s quadrant’ (Stokes 1997), ‘third mission activities’ (Pålsson et al. 2009; Göransson et al. 2009; Krücken et al. 2009; Gregersen et al. 2009; Ca 2009) and ‘academic entrepreneurial cultures’ (Göktepe-Húlten 2008). Potentially, society can benefit from academic research in various ways, ranging from contributions to culture and education to specific insights or products with economic or socio-political value. Despite the stronger emphasis on societal impact in science policy and the numerous theoretical contributions, empirical studies on the generation of societal impact are scarce. In this paper, our aim is to contribute empirical evidence on how the quest for societal relevance is taken up by principal investigators.[1] We investigate five research questions: (1) What are the opinions of research leaders about the increasing emphasis on the societal impact of research? (2) Which different types of *direct* societal output products do they produce? After having answered these questions, we focus on the *indirect* way of realising societal impact: (3) How is societal orientation reflected in scholarly output? We answer this third research question for virology, one of the core fundamental research fields in the domain under study. Next, we address two highly debated issues that might explain research leaders' opinions about societal relevance and their societal performance. First, it is often argued that academic excellence automatically produces societal relevance: the latter does not need to be encouraged. Others argue that a focus on societal relevance endangers academic research. Such a focus may hinder fundamental research due to a premature search for applications. Therefore, the next question is: (4) How are societal and scholarly productivity related? Secondly, policy makers are looking for ways to encourage socially relevant research. This leads to the last question: (5) How does management and organisation of research, such as funding arrangements and the characteristics of research groups, influence societal performance?

In this paper, we focus on the biomedical and health disciplines. The primary reason for this is their obvious societal role in improving health and wellbeing. Progress made in biomedical and health research over the years has resulted in an increased quality of life and a reduced mortality and morbidity (Garcia-Romero 2006). Biomedical and health research has a dual mission; it is concerned with both the production of scientific knowledge and with the utility and implementation of scientific achievements in the health care system (Council for Medical Sciences 2002). The dual mission refers to the concept of translational research. Translational research aims not only to obtain fundamental knowledge, but also to translate this knowledge into applicable treatments: research that seeks to move from bench to bedside; from laboratory experiments to actual point-of-care patient applications (Woolf, 2008).[2] Therefore, research evaluations should not only focus on the scientific performance of biomedical and health research, but also take its societal quality into account.

Secondly, biomedical and health disciplines make up about 40% of all research in the Netherlands, as in many other developed countries, and it covers a wide variety of research types. We distinguish between three research types based on their relationship with patients: (1) para-clinical groups with an advisory relationship with patients and mostly a 'social sciences' research perspective (e.g. social medicine, public health and medical psychology); (2) pre-clinical groups with little or no patient contact and laboratory-based fundamental research (e.g. immunology, micro-biology and neurosciences); and (3) clinical groups with direct patient contact and an application-oriented type of research (e.g. dermatology, nephrology and psychiatry). Therefore, the results can be generalised to a broad range of research fields.

Thirdly, biomedical and health research is heavily dependent on external research funding (Ellenbroek et al. 2002; Van der Weijden 2007). Scientists, research groups and organisations are accountable for their use of funds to a range of public, not-for-profit (charities) and commercial sources. Consequently an evaluation of how and why biomedical and health research delivers social benefits is crucial to the stakeholders, who include government, a variety of funders, industry, regulatory bodies, patients and the general public (UK Evaluation Forum 2006). In other words, societal relevance (Hessels et al. 2009) is currently at the core of the relationship between academic biomedical and health science and society. This underlines the importance of further improving the close relationship between academic research and clinical practice, and the dialogue with stakeholders.[3] Hemlin and Rasmussen (2006) argue that discussions about the societal value of academic science have consequences for research evaluations, which should now be viewed as an open monitoring system in which scientific, industrial and public actors connect in a dynamic dialogue. However, project selection and research evaluation procedures do not usually cover the societal value of academic research in an explicit manner, and explicit criteria developed for this purpose are still in their infancy. Indicators to measure societal relevance are not available (Atkinson-Grosjen and Douglas 2010; De Jong et al. 2011). Within the Dutch context, ZonMw,[4] the Dutch research council for biomedical and health research, is one of the first councils that takes societal relevance explicitly into account in its selection procedures.

### 1.1 Methods for evaluating societal impact

In the meantime, several attempts have been made to develop methods for evaluating the societal relevance of research. One example is the project Evaluating Research in Context (ERiC) (and the related EU-funded SIAMPI project)[5] which recently carried out pilot studies within Dutch universities, in various disciplines, such as architecture, electrical engineering, mechanical engineering, nanoscience, computer science and law (see De Jong et al. 2011, for a brief overview). Another example is the study by Meagher et al. (2008) who developed a method to assess the impact of social science research conducted in the UK on policy and practice. Also worth mentioning here is the study by Laredo and Mustar (2000), which proposed a method to characterise the activity profile of research laboratories as a research compass card. They argue that besides contributing to the production of scientific knowledge and to education and training, laboratories

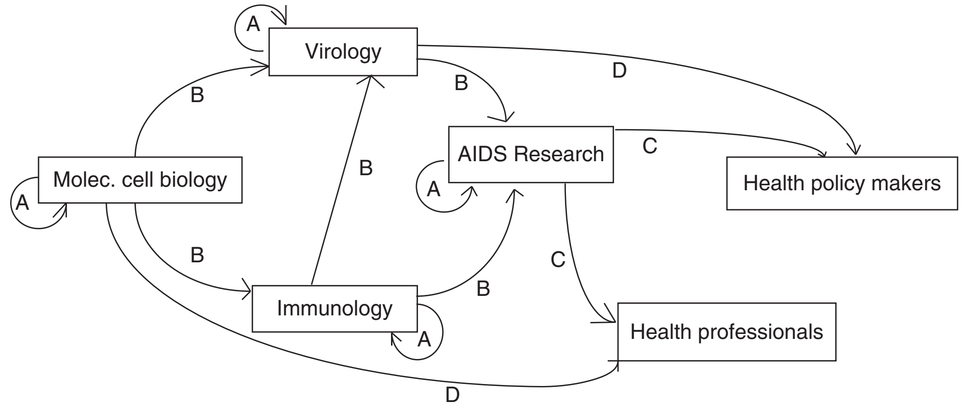


**Figure 1.** Interaction between research and societal audiences.

are also involved in the creation of competitive advantages and of public and collective goods, and participate in the public debate. Indicators to measure these activities are presented. Unfortunately, examples of indicators that measure the participation of laboratories in the public debate were not explicitly described. Finally, Merkx and Van den Besselaar (2008) proposed an approach to evaluate the societal relevance at the research field level, and applied this to coastal research.

Within biomedical and health research, specific methods have been proposed and applied—the biomedical and health fields seem to be leading in this respect (Lyall et al. 2004). The three best known research evaluation frameworks (for an overview see Brutscher et al. 2008) used in health research are: first, the Payback Framework, developed in the UK by Buxton and colleagues (Buxton and Hanney 1996; Hanney et al. 2003; 2004). It describes the wide range of health-related research and the social and economic benefits that may result from biomedical research projects and programs. The Canadian Academy of Health Sciences (2009) designed the CAHS impact framework which builds on the Payback Framework. It can be used to describe impact at various levels (individual, provincial, national and international), and to define funders returns by quantifying the value of impact on end-users in dollars invested. Secondly, the Research Institute Framework was developed by the Royal Netherlands Academy of Arts and Sciences (KNAW) (Council for Medical Sciences 2002) in the Netherlands. It measures the societal impact of health care research on the level of research institutes. Thirdly, there is the Societal Impact Framework (van Ark and Klasen 2007), which focuses on communication between researchers and a variety of stakeholders. Within this framework, the societal outcomes of research are evaluated in terms of the quality of the various communication processes. Some work has been done on the application of the frameworks in order to improve our understanding of societal impact, i.e. how research is translated from bench to bedside (e.g. Nason et al. 2007; Oortwijn 2007; Advisory Council on Health Research 2007). Elements of these frameworks were used in the construction of our questionnaire.

## 1.2 Societal relevant output and societal impact

The impact of research is generated through the communication networks. That holds for scholarly impact on peers in the field, for scholarly impact in other fields and for societal impact. Researchers produce output for peers and for other (societal) audiences. The quality and impact of the output is decided by the specific audiences that it is intended for. Impact can be measured in terms of the reaction of an audience on the output. For example, scientific impact becomes visible through actions such as citations and downloads, or through sales of papers or books. Societal impact may become visible through invitations for participating in advisory committees, or through the adoption of medical guidelines. Within this perspective, we distinguish between direct and indirect societal impact (De Jong et al. 2011).

First, societal impact can be produced directly by producing non-scholarly output for stakeholders, based on the *expertise* of the researchers who are involved. Non-scholarly means that the output is not meant for peers in the field, but for the other audiences such as the general public, policy makers and medical professionals. These interactions are represented by arrows (C and D) in Fig. 1.

With regard to directly generated societal impact, there is a variety of 'non-scholarly' output of research that may contribute to the improvement of health and wellbeing, such as advice on new treatments, policy advice and plans for organising healthcare systems, strategies for health care innovation, or informing the general public about health risks. These outputs can—just as scholarly output—be measured at the group level.

Secondly, societal impact can be produced indirectly where research output (new knowledge) is taken up by other researchers (B arrows) who, in turn, use it in their own research that leads to results relevant for stakeholders (C arrows), such as medical professionals working in hospitals.

Indirectly generated societal impact refers to biomedical and health research results in academic papers, with new knowledge that may—when taken up in patient care, drugs or instruments—contribute to the improvement of health and to new treatments for diseases. Sometimes the contributions may be the effect of serendipity, but biomedical and health research is often explicitly directed at scholarly problems that have to be solved in order to make progress in curing or preventing diseases. For example, fundamental results in molecular cell biology may inform basic research in virology and immunology. The results of the two latter fields may in turn inform AIDS research which produces useful therapies to be used in patient care. In other words, fundamental research results are taken up in a sequence of steps by other, more applied researchers, and finally by professionals. In biomedical research, a concept has been introduced for this: translational research.

In this paper, we focus on the direct link between researchers and societal audiences. However, we will show for one case (virology) that societal orientation is visible through indirect links.[6]

## 2. Data and methods

### 2.1 A survey among research leaders

The data were collected in 2007 in a survey among biomedical and health research leaders (principal investigators) employed by university medical centres (UMCs) or by biomedical public research institutes in the Netherlands (Van der Weijden 2007; Van der Weijden et al. 2008; 2009). Names and addresses were obtained from administrative records. A mail strategy was chosen to collect the data because principal investigators are difficult to reach by phone or in person and have, due to their heavy workload (including patient care duties), limited access to the web. In total, 188 group leaders returned a completed questionnaire by post, resulting in an overall response rate of 27%, which seems acceptable regarding the target population and chosen strategy (the norm is 36% $\pm 13$ (Baruch 1999)). To maximise the response rate, we used the tailored design method (Dillman 2000).

We obtained information about the research leaders' opinions on societal impact of research. We used five-point Likert scales, with answers ranging from totally agree to totally disagree. The research leaders were also asked to indicate which types of societal output were realised (Table 1), including an estimation of the quantity of societal output in the period 2004–6. Elements of three societal impact frameworks discussed in Section 1.1 were used to construct these questions.

**Table 1.** Ten types of societal output

| |
|---|
| 1 Presentations to non-scientific public (professionals, policy makers or patients) |
| 2 Contributions to public media (TV, radio or newspaper) |
| 3 Education for professionals and policy makers, such as retraining courses |
| 4 Contributions to symposia and conferences directed to societal communities |
| 5 Membership of committees that are developing guidelines or policy recommendations |
| 6 Publications in professional or policy journals |
| 7 Clinical guidelines |
| 8 Policy reports |
| 9 Editorships of professional medical and health journals |
| 10 Membership of committees of funding organisations, such as charities |

The scholarly performance[7] was measured by the number of publications in journals indexed in the Web of Science of which the principal investigator was a (co-)author. Impact is measured as citations per full-time researcher (FTE). Finally, the survey contained questions about: (1) organisational characteristics (i.e. funding sources); (2) managerial characteristics (i.e. leadership experience); and (3) disciplines of the groups' research within biomedical and health research (among others, health care research, immunology and dermatology) (Van der Weijden 2007; Van der Weijden et al. 2008, for more detail about the survey design).

### 2.2 Non-response analysis

Non-response analysis shows that the respondents can be regarded as a representative sample of the Dutch biomedical and health research groups. First, we checked whether the respondents were evenly distributed among the various research institutions and the sub-disciplines, and this proved to be the case. Secondly, we compared scholarly performance of respondents and non-respondents. Since publication counts are highly skewed, a Mann–Whitney test was used. Respondents did not significantly differ ($Mdn = 25.0$) from non-respondents ($Mdn = 23.0$), $U = 62{,}315.0$, $p = 0.365$, $r = -0.03$. The mean difference between the two groups was also small (33 publications for respondents versus 31 for non-respondents).

### 2.3 Some characteristics of the sample

The biomedical and health leaders in the sample supervised research groups with an average size of 17 FTE staff members. The average age of the respondents was 53 years in 2007, and the majority were male (87%). Most of the leaders had been functioning as heads of their research groups for a long time: on average 12 years. In 74% of the cases, the respondents indicated that they had a co-leader. Research leaders spent their time on research, management, supervision, education and patient care. Most groups (87%) were located in a UMC and the others (13%) were working in public research institutes. Of the 188 respondents, 34 were leaders of para-clinical research groups, 73 were research leaders of pre-clinical research groups and 81 were research leaders of clinical research groups. Writing and publishing scientific articles (90%), developing new knowledge (55%) and training young researchers (36%) were reported to be the most important goals of the research groups.

### 2.4 Analysing indirect societal impact of biomedical research

In order to map the application orientation of basic biomedical research, we selected a core, basic research field: virology. By analysing the journal citation network of the main journal in this field (*Journal of Virology*), we identified the relevant virology journals, as well as research fields that are a knowledge source for virology and fields that are using knowledge taken from virology. This informs us about the relationships between virology and its applications in clinical and health care oriented research, in other words, about the relationship between societal impact and fundamental research. In the second step, we analysed the titles and keywords of all papers in virology journals in order to identify words that refer to the application context of virology knowledge in medical treatments. The more frequently these title words and keywords appear, the stronger the application orientation of fundamental research. We repeated the analysis for a variety of years, in order to identify changes in application orientation and in the practical contributions of virology research. The details of the methods are explained elsewhere (Van den Besselaar 2000; Van den Besselaar and Heimeriks 2006).

## 3. Findings

### 3.1 Societal orientation of research leaders

Science policy makers and research managers increasingly emphasise that research should be useful for society. This is not received enthusiastically everywhere. For example, a UK study suggests that researchers who engage in popularisation are seen as 'lesser' researchers by their peers, and that many think that societal output is produced by researchers 'who are not good enough for an academic career' (Royal Society 2006). What is the opinion of biomedical and health research leaders about this? Are they working in an ivory tower, or do they also consider societal relevance to be of great importance? In the survey, we asked whether the increasing emphasis on societal impact has implications for research group goals. Do research group leaders take societal relevance into account when formulating the group's research agenda? And in their research, are they focusing on existing medical problems and useful innovations? As Fig. 2 (and Table A1) indicates,

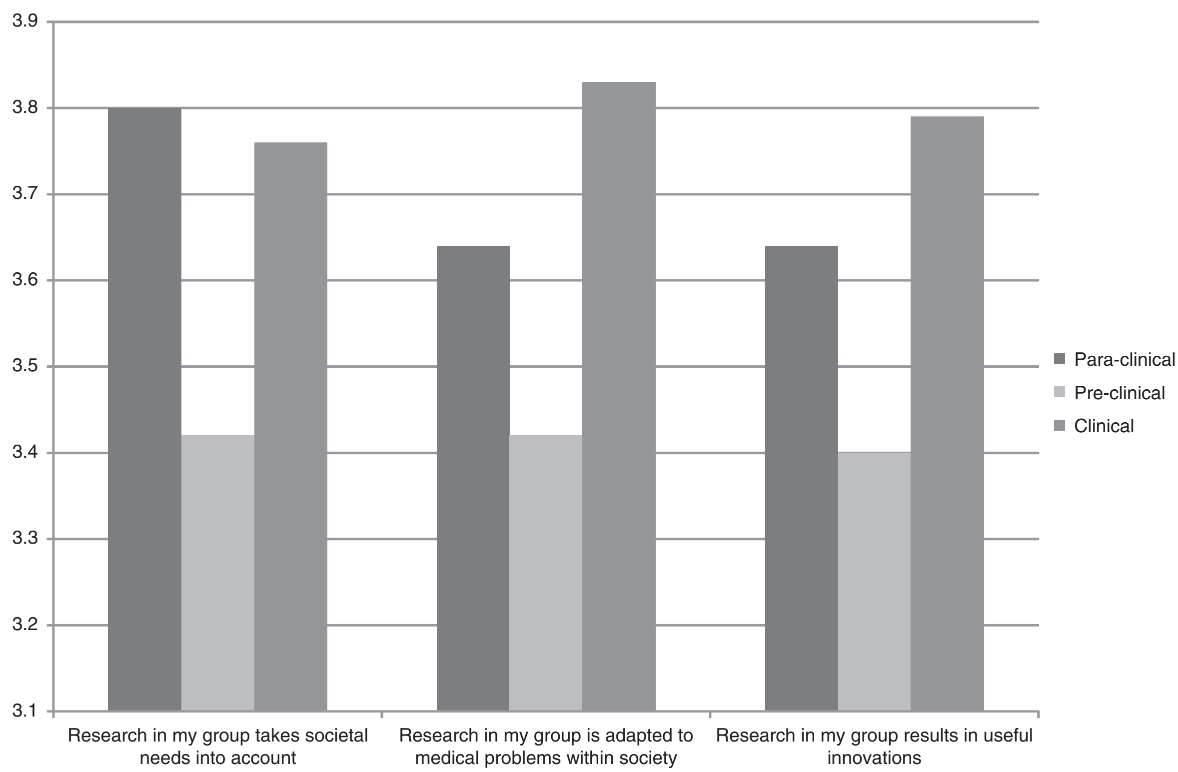


**Figure 2.** Opinions of research leaders on societal research goals.

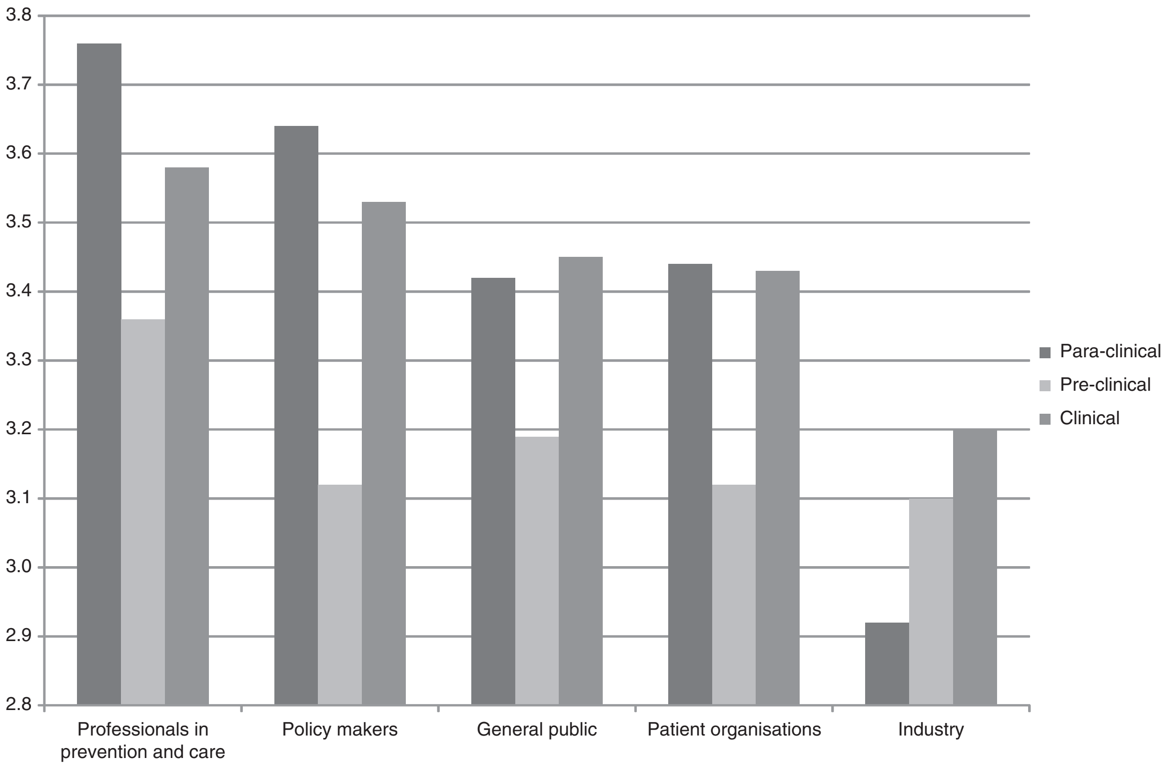


**Figure 3.** Opinions of research leaders on increased interactions with stakeholders.

the attitude of research leaders towards societal research goals is, on average, slightly positive. Compared to para-clinical and clinical leaders, pre-clinical research leaders had more neutral views.[8]

Does this positive attitude towards societal orientation in research translate into interactions with stakeholders? When asked about the effects of the recent increase in emphasis on societal impact, research leaders reported a slight increase of interactions with various stakeholders (Fig. 3 and Table A2). Overall, respondents had neutral views about changes in their interactions with professionals in prevention and care, policy makers, the general public, patient organisations and (pharmaceutical) industry and firms. In general, pre-clinical group leaders had more neutral attitudes towards the improved interactions with stakeholders compared to para-clinical and clinical leaders, similar to their opinion on societal research goals. Interactions with industry show a slightly different pattern: group leaders from all three disciplines do not report intensified interaction[9] with companies (see Fig. 3).

The next question is whether the increasing emphasis on the societal impact of biomedical and health research results in knowledge dissemination. Does it result in more or better: (1) knowledge exchange with, (2) knowledge products for, and (3) knowledge use by stakeholders? In general, research leaders had neutral views (see Fig. 4 and Table A3). They perceived only minor improvements in the exchange of scientific knowledge with their stakeholders. Again, pre-clinical group leaders predominantly had a more neutral view about the improved knowledge dissemination with stakeholders, while para-clinical and clinical group leaders were somewhat more positive.[10]

The last question is whether research leaders' views on the importance of societal research goals are related to interactions with and knowledge dissemination to various societal stakeholders. Indeed, the more positive the opinions are about societal orientation of research, the higher the level of perceived interactions with various stakeholders; and the more perceived knowledge exchange with, the more knowledge products for, and the more knowledge use by stakeholders (see Table 2). The correlations found are moderate (>0.25) to strong (>0.50). Of course, these results are based on self-reporting, and those who think societal impact is important, may be more inclined to report interaction with stakeholders and knowledge dissemination. However, we did not ask whether or not interaction with and dissemination to stakeholders took place, but how much the interaction was increased—and most principal investigators answered the question (see the Ns in Table 2).

In summary, biomedical and health research leaders are, on average, slightly positive about the increased societal orientation of their research. Pre-clinical research leaders have more neutral views, which are easy to understand, as pre-clinical research is more 'fundamental' and therefore—in general[11]—more distantly related to care, cure and health policy issues. The more positive research leaders are about taking into account societal impact when

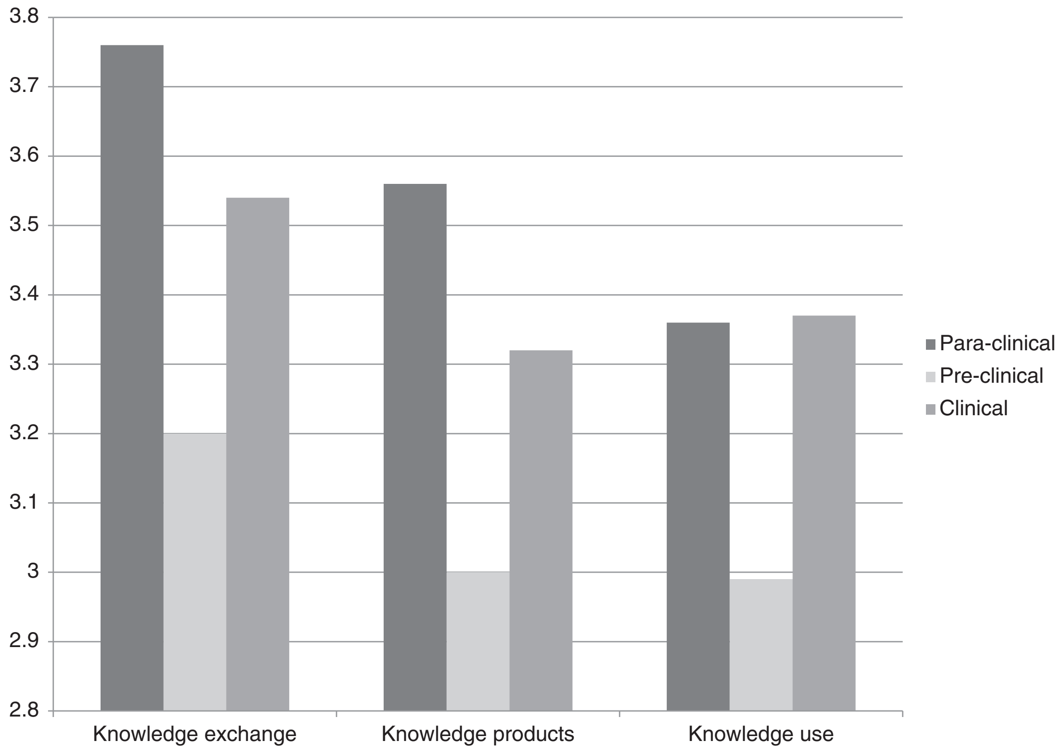


**Figure 4.** Opinions of research leaders on increased knowledge dissemination to stakeholders.

**Table 2.** Societal research goals by interaction with stakeholders and knowledge dissemination (Spearman's rho)

| Societal research goals | Interaction with stakeholders | | | | | Knowledge dissemination | | |
|---|---|---|---|---|---|---|---|---|
| | Professionals in prevention and care | Policy makers | General public | Patient organisations | Industry | Knowledge exchange | Knowledge products | Knowledge use |
| Research in my group takes societal needs into account | 0.553* N = 182 | 0.409* 182 | 0.390* 182 | 0.450* 183 | 0.267* 182 | 0.520* 178 | 0.557* 177 | 0.503* 178 |
| Research in my group is adapted to medical problems within society | 0.366* 182 | 0.318* 182 | 0.287* 182 | 0.382* 183 | 0.275* 182 | 0.520* 178 | 0.455* 177 | 0.518* 178 |
| Research in my group results in useful practical innovations | 0.474* 182 | 0.469* 182 | 0.342* 182 | 0.380* 183 | 0.338* 182 | 0.572* 178 | 0.562* 177 | 0.582* 178 |

*p < 0.001

formulating the group's research agenda, the more positive they are about interactions with stakeholders, and the more they think it results in knowledge dissemination to stakeholders.

## 3.2 Societal output of biomedical and health research groups

Whereas the previous section was about the *societal orientation* of research leaders, we turn in this section to the *non-scholarly output of research*. The biomedical and health groups produced different types of societal research output. Products can be 'tangible', such as reports, but we also included productive interactions with stakeholders as output (Evaluating Research in Context 2010). Table 3 lists the different products, the percentage of groups producing these types of output and the amount produced (see also Table A2).

The most frequently mentioned products are: (1) presentations about research results to non-scientific audiences, such as professionals, patients and the general public; (2) presentations in public media, such as TV, radio and newspaper, in order to communicate research findings to the general public; and (3) educational activities for professionals in the private sector, policy sector or in prevention and care, by 84%, 76% and 69% of the

**Table 3.** Societal output of Dutch biomedical and health groups (2004–6)†

| | | | Active in generating output | Reported quantity of output |
|---|---|---|---|---|
| 1 | Presentations to non-scientific public | Percentage of groups | 84% | 63% |
| | | Mean of output | | 8.9 |
| 2 | Contributions to public media | Percentage of groups | 76% | 57% |
| | | Mean of output | | 7.0 |
| 3 | Education/courses for professionals | Percentage of groups | 69% | 47% |
| | | Mean of output | | 6.9 |
| 4 | Membership of committees developing guidelines/policy recommendations | Percentage of groups | 67% | 48% |
| | | Mean of output | | 3.0 |
| 5 | Contributions to conferences directed to stakeholders | Percentage of groups | 66% | 48% |
| | | Mean of output | | 7.0 |
| 6 | Professional publications | Percentage of groups | 65% | 48% |
| | | Mean of output | | 17.5 |
| 7 | Clinical guidelines | Percentage of groups | 54% | 41% |
| | | Mean of output | | 2.7 |
| 8 | Policy reports | Percentage of groups | 38% | 27% |
| | | Mean of output | | 2.8 |
| 9 | Editorship of societal-oriented biomedical and health journals | Percentage of groups | 38% | 22% |
| | | Mean of output | | 2.5 |
| 10 | Membership of committees funding societal-oriented biomedical/health research | Percentage of groups | 34% | 26% |
| | | Mean of output | | 2.5 |

†N = 184, four missing values

research groups, respectively. Research leaders could easily indicate whether a specific type of societal output has been produced, but found it difficult to estimate how much. On average, only half of the research leaders reported this.

In general, we did find a moderate positive relationship between the societal orientation of research leaders and societal research output.[12] In other words, research leaders who have more positive views about societal research goals, improved interaction with stakeholders and growing knowledge dissemination to stakeholders are more active in realising societal output.

Differences exist among medical disciplines concerning societal research output. In general, para-clinical groups are most active and productive in realising societal output, while pre-clinical groups are least active and productive in realising societal output (Table 4).[13] In particular, para-clinical groups are significantly more active in realising policy reports and in participating in committees for funding societal-oriented research than pre-clinical and clinical groups. Pre-clinical groups are significantly less active in participating in committees for developing guidelines or policy recommendations and in generating professional publications. Moreover, para-clinical groups were also more productive than their pre-clinical and clinical colleagues. They were significantly more productive in giving presentations to non-scientific audiences, contributing to the public media, writing policy reports and participating in funding committees that stimulate societal biomedical and health research. In contrast, pre-clinical groups were less productive in comparison with their para-clinical and clinical colleagues. Specifically, they were significantly less productive in giving presentations and educating or giving courses to policy makers or professionals, and they were less often members of committees that develop guidelines or policy recommendations.

In conclusion, biomedical and health research groups produce a variety of societal research output. Para-clinical researchers are the most active and productive in this respect, while clinical researchers are more active and productive than the pre-clinical researchers. Furthermore, research leaders who are more positive about the increased emphasis on societal impact are more active in realising societal output. Finally, it seems that research leaders are not familiar with reporting the amount of societal output.

### 3.3 Health care relevance of biomedical research: the virology case

Section 3.2 addressed the direct way of creating societal impact by producing non-scholarly output. In contrast, this section focuses on the indirect way of creating societal impact. In particular, we investigate whether or not fundamental (pre-clinical) biomedical research is oriented at societal health care issues, and whether or not that has changed over time. As research programmes have to generate expectations of relevance in order to acquire funding, the research programmes do not seem appropriate places to study the societal orientation of research. A better way of finding indicators for societal orientation may be found in research output. Two indicators come to mind. First, are fundamental biomedical

**Table 4.** Societal output of research groups by discipline (2004–6)†

| Societal output | | Para-clinical groups | | Pre-clinical groups | | Clinical groups | |
|---|---|---|---|---|---|---|---|
| | | Active in generating output | Reported quantity of output | Active in generating output | Reported quantity of output | Active in generating output | Reported quantity of output |
| Presentations | % groups | 92.0% | 68% | 77.2% | 63% | 87.5% | 61% |
| | Mean units per FTE | | 1.67* | | 0.30* | | 0.44 |
| Public media | % groups | 84.0% | 64% | 65.8% | 52% | 82.5% | 59% |
| | Mean units per FTE | | 0.72* | | 0.34 | | 0.39 |
| Education/courses | % groups | 84.0% | 56% | 59.5% | 43% | 72.5% | 48% |
| | Mean units per FTE | | 0.74 | | 0.26* | | 0.55 |
| Cie's developing guidelines/policies | % groups | 80.0% | 60% | 51.9%* | 39% | 77.5% | 54% |
| | Mean units per FTE | | 0.29 | | 0.13* | | 0.20 |
| Conferences/symposia | % groups | 80.0% | 60% | 50.6% | 41% | 77.5% | 51% |
| | Mean units per FTE | | 0.57 | | 0.28* | | 0.45 |
| Professional publications | % groups | 92.0% | 60% | 46.8%* | 39% | 75.0% | 53% |
| | Mean units per FTE | | 1.08 | | 0.79 | | 1.32 |
| Clinical guidelines | % groups | 52.0% | 40% | 39.2% | 30% | 70.0% | 51% |
| | Mean units per FTE | | 0.20 | | 0.13 | | 0.22 |
| Policy reports | % groups | 76.0%* | 60% | 25.3% | 19% | 38.8% | 24% |
| | Mean units per FTE | | 0.44* | | 0.11 | | 0.10 |
| Editorship societal-oriented journals | % groups | 48.0% | 36% | 29.1% | 20% | 43.8% | 29% |
| | Mean units per FTE | | 0.22 | | 0.18 | | 0.15 |
| Cie's funding societal-oriented research | % groups | 64.0%* | 48% | 24.1% | 19% | 33.8% | 29% |
| | Mean units per FTE | | 0.26* | | 0.12 | | 0.14 |

†n = 25 para-clinical groups (one missing value); n = 79 pre-clinical groups (one missing value); $n$ = 80 clinical groups (two missing values)
*Significantly different at $p < 0.05$

journals cited by the more applied ones that focus on clinical problems? In other words, is basic biomedical research a knowledge input for clinical research that is more directly oriented towards medical practice? Secondly, are fundamental biomedical research papers addressing important health-related issues?

We use virology, one of the pre-clinical research fields, as an example. The *Journal of Virology* is the most cited journal in the field. Analysing the citation environment of this journal, we found the citation network of virology research as presented in Table 5. The columns give the distribution of references from the field indicated in the column heading over the research fields represented in the rows. In the core of the network is the virology cluster, consisting of some 20 virology journals. As shown in Table 5, virology draws heavily on molecular cell biology: 23.7% of all citations from the virology cluster refer to this research field. Virology journals also often cite immunology journals (8.3%) and the main multidisciplinary journals *Science* and *Nature* (7.9%). Smaller knowledge sources for virology are AIDS research and research on infectious diseases, vaccine research and immunology.

Taking the perspective from more application-oriented research fields, such as AIDS research and vaccine research (the last two columns), we can identify whether or not virology is a knowledge source for these fields. Both fields cite virology journals heavily, indicating the relevance of virology for these more applied fields. These citation patterns suggest that the knowledge exchange between pre-clinical fields (virology, but also in this case molecular biology, and immunology) and the clinical fields (AIDS, infectious and tropical diseases, vaccine research) is fairly intensive. We compared this pattern with previous years, and the citation network is stable.

Another indicator of societal orientation is based on the titles of papers in virology journals. Do the titles point at diseases and therapies, or at fundamental cellular and biological processes, including laboratory techniques? Table 6 lists the most frequently occurring title words and author keywords. Many of these refer to either clinically important viruses that cause human infections, or therapies and drugs (italics in Table 6). This pattern has also been stable over the years.

If we generalise the findings on virology, we may conclude that pre-clinical ('fundamental') fields are strongly oriented to clinical issues. Moreover, citation relations show that they inform the clinical fields to a considerable extent. In other words, the increased attention to the societal benefits of research does not appear to be related to a lack of such relevance. Rather, it may more strongly reflect the quest for a clearer engagement with societal relevance through the direct communication with a variety of societal stakeholders.

**Table 5.** Knowledge streams in virology citation network

| | Virology | Molecular cell biology | Immunology | Multidisciplinary science[a] | AIDS and infectious diseases | Vaccine research |
|---|---|---|---|---|---|---|
| Virology | 55.2% | 3.4% | 4.5% | 2.1% | 19.7% | 25.7% |
| Molecular cell biology | 23.7% | 71.7% | 26.1% | 36.3% | 10.0% | 10.0% |
| Immunology | 8.3% | 6.6% | 55.7% | 5.0% | 16.8% | 19.8% |
| Multidisciplinary science† | 7.8% | 17.9% | 12.1% | 56.2% | 8.1% | 7.1% |
| AIDS and infectious diseases | 3.8% | 0.3% | 1.2% | 0.4% | 42.5% | 9.7% |
| Vaccine research | 1.2% | 0.1% | 0.5% | 0.1% | 2.9% | 27.7% |

†This set consists of journals such as *Science*, *Nature* and *PNAS*

**Table 6.** Title words and author keywords of papers in virology journals

| Word | freq | Word | freq | Author keyword | Freq | Author keyword | Freq |
|---|---|---|---|---|---|---|---|
| Virus | 2447 | *Cytomegalovirus* | 125 | *HIV1* | 86 | *HBV* | 25 |
| *Human* | 920 | Identification | 122 | *HIV* | 85 | *West Nile virus* | 25 |
| Protein | 767 | Genetic | 118 | Real time pcr | 74 | Replication | 24 |
| *Infection* | 726 | Binding | 116 | *Rotavirus* | 48 | Molecular epidemiology | 24 |
| Cells | 433 | Genome | 115 | *Hepatitis C virus* | 48 | Elisa | 24 |
| *Hepatitis* | 401 | T-cell | 112 | Pcr | 48 | *Epstein-Barr virus* | 24 |
| Immunodeficiency | 384 | Acute | 108 | Rtpcr | 45 | *Flavivirus* | 24 |
| *HIV* | 375 | Envelope | 106 | Genotype | 45 | Genotyping | 23 |
| Viral | 350 | Entry | 105 | Phylogenetic analysis | 44 | *Baculovirus* | 23 |
| RNA | 270 | Assay | 104 | *Norovirus* | 44 | *SIV* | 22 |
| Replication | 253 | Sequence | 103 | Interferon | 38 | Detection | 21 |
| *Influenza* | 235 | Murine | 102 | *Cytomegalovirus* | 36 | *HPV* | 21 |
| Expression | 219 | Activity | 101 | *Adenovirus* | 35 | *Influenzavirus* | 21 |
| Cell | 212 | *Vaccine* | 99 | Apoptosis | 33 | *Enterovirus* | 21 |
| Gene | 188 | Antibody | 99 | *Vaccine* | 31 | *Resistance* | 20 |
| Characterisation | 186 | Activation | 99 | *Gastroenteritis* | 30 | *Children* | 20 |
| DNA | 170 | Receptor | 98 | *Epidemiology* | 29 | *Ribavirin* | 19 |
| *Disease* | 169 | *Papillomavirus* | 97 | *Influenza* | 29 | *Influenza A virus* | 19 |
| *Herpes* | 156 | Region | 96 | *Hepatitis B virus* | 28 | Neutralisation | 19 |
| *Respiratory* | 147 | Responses | 92 | Real time rtpcr | 28 | *SARS-CoV* | 18 |
| Simplex | 142 | Real-time | 91 | Genotypes | 28 | *Human cytomegalovirus* | 18 |
| *Patients* | 131 | Cellular | 90 | *HCV* | 27 | *Coinfection* | 17 |
| Mice | 129 | Domain | 90 | *Diagnosis* | 27 | Innate immunity | 17 |
| Molecular | 128 | *Herpesvirus* | 90 | Pathogenesis | 25 | *Gene therapy* | 17 |

### 3.4 Societal and scientific productivity

It is often argued that societal orientation negatively influences the scholarly quality of research (Royal Society 2006). However, studies measuring societal output and scholarly performance show different results. A study of Norwegian university professors (Gulbrandsen and Smeby 2005) measured the entrepreneurial output of researchers in terms of whether or not R&D activities had resulted in commercial results such as patents, products, establishment of firms, and consulting contracts.[14] This study found that entrepreneurial output is not significantly related to academic output. A study of societal quality in a UMC in the Netherlands (Mostert et al. 2010) showed no relationship between societal and scientific quality. Finally, a French study (Jensen et al. 2008) examined the relationship between popularisation activities (e.g. public or school conferences, interviews in newspapers, collaboration with associations) and academic activities (number of papers and citations). This study found that the various disciplines differ in this respect. No relationship was found between engineering and chemistry, but a modest positive relation was found between the life sciences. Van Looy et al. (2011) recently showed that at university level scientific productivity is positively associated with entrepreneurial performance, measured as patents, spin-offs and contract research. A similar relation also holds at the level of the individual academic researcher, as shown

**Table 7.** Societal productivity per category by scientific productivity and impact†

| | Spearman's rho | | *N* |
|---|---|---|---|
| | Scientific productivity | Scientific Impact | |
| Presentations to non-scientific public | −0.007 | −0.190** | 114 |
| Contributions to public media | −0.071 | −0.235** | 101 |
| Education/courses for professionals | −0.102 | −0.217** | 84 |
| Membership of committees developing guidelines/policies | 0.000 | −0.085 | 88 |
| Contributions to conferences directed to stakeholders | −0.046 | −0.177* | 86 |
| Professional publications | 0.012 | −0.051 | 86 |
| Clinical guidelines | −0.065 | −0.211* | 74 |
| Policy reports | −0.052 | −0.239* | 48 |
| Editorship of societal-oriented journals | −0.241 | −0.357** | 47 |
| Membership of committees funding societal-oriented research | −0.006 | −0.160 | 40 |

†Mentioned type of societal output (units per FTE) is by scientific output (papers per FTE) and impact (citations per FTE)
*$p < 0.10$, **$p < 0.05$

by van Looy et al. (2006): the more prolific scientists emerge as those who are more likely to patent.

We answer this question for Dutch biomedical and health research. Research quality is high in this domain, when measured in publication volume and citation impact (NOWT 2010). In the period 2004–6, the biomedical and health groups in our sample published an average of 1.9 papers per FTE (29 papers per group) in journals indexed in the Web of Science. As Table 7 indicates, no significant correlations exist between the scientific and societal productivity of the research groups. This holds for all types of societal output considered in this study. However, there is evidence suggesting a moderate negative correlation between societal output and scientific impact (Table 7). More specifically, scientific impact correlates negatively with most types of societal output—apart from professional publications, clinical guidelines and grant allocation committee membership. These types of societal output seem more closely related to scholarly output (professional publications and medical guidelines) than the others (information for the general public, and for societal stakeholders, education and editorial work).

Summarising, societal relevant output does not automatically follow from highly productive research, but neither does it hinder productive research. Several types of societal output do not seem to hinder high-impact research, but others do. This is probably because it is uncertain whether investing time in these activities will result in scholarly spin-offs. This leads to the next, and last question of this paper: under which conditions can research simultaneously be of high scholarly and societal quality?

## 3.5 Management, organisation and societal output of research groups

The fifth question we address is to what degree the management and organisational characteristics of biomedical and health research groups might influence societal output. In other words, we investigate whether or not managerial and organisational conditions such as: the influence of funding profiles, leadership experience, group size, work environment and translational research, are related to societal orientation and the output of research groups.

***3.5.1 Funding.*** Biomedical and health research increasingly depends on external funding. Consequently, research councils and other funding organisations place an emphasis on societal relevance, which may influence the research strategies and, as a consequence, the level of the societal output of groups. How do the various modes of research funding influence the production of societal output? In order to answer that question we distinguish between four different funding arrangements, each with different conditions: (1) (basic) institutional funding; (2) funding by research councils; (3) commissioned research funded by industry or government; and (4) funding by charities. Research groups differ in their strategies, possibilities and capabilities for attracting funding from these sources, which results in different funding profiles. Do these profiles relate to the quantity of societal output of research groups? Table 8 shows the correlations between the percentage of funding coming from the different sources and the quantity of societal output.

Institutional funding correlates positively with the quantity of societal output. Groups with a relatively high percentage of institutional funding produced, for instance, more clinical guidelines and participated more intensively in societal committees and editorial boards.

We did not find any positive relationship between the proportion of funds coming from (pharmaceutical) industries, companies or government ministries and the societal output of biomedical and health research groups. In fact, biomedical and health groups that receive a high percentage of funding from these sources mostly conduct

**Table 8.** Societal productivity by funding source†

| | Institutional Funding | Industry and ministries | Charities | All councils | *N* |
|---|---|---|---|---|---|
| | | Spearman's rho | | | |
| Presentations to non-scientific public | | | 0.287*** | | 109 |
| Contributions to public media | | | −0.420*** | | 99 |
| Education/courses for professionals | | | −0.267** | | 82 |
| Membership of committees developing guidelines/policy recommendations | 0.183* | | −0.193* | | 84 |
| Contributions to conferences directed to stakeholders | | | −0.379*** | | 86 |
| Professional publications | | | | | |
| Clinical guidelines | 0.288** | | | | 69 |
| Policy reports | 0.280* | | −0.307** | | 46 |
| Editorship of societal-oriented journals | 0.355** | | | | 46 |
| Membership of committees funding societal-oriented research | | −0.453*** | | | 46 |

†Percentage of funding from mentioned source
*p < 0.10, **p < 0.05, ***p < 0.01

**Table 9.** Societal productivity by ZonMW-activity†

| | Spearman's rho | *N* |
|---|---|---|
| Presentations to non-scientific public | 0.352*** | 114 |
| Contributions to public media | 0.240** | 101 |
| Education/courses for professionals | 0.225* | 84 |
| Membership of committees developing guidelines/policy recommendations | 0.205* | 88 |
| Contributions to conferences directed to stakeholders | 0.272** | 84 |
| Professional publications | | |
| Clinical guidelines | | |
| Policy reports | 0.373*** | 48 |
| Editorship of societal-oriented journals | | |
| Membership of committees funding societal-oriented research | 0.428*** | 40 |

†ZonMw activity is number of proposal submissions and received grants normalised for group size
*p < 0.10, **p < 0.05, ***p < 0.01

contract research with a societal or economic goal for these societal stakeholders.[15] In other words, we assume that the societal output is anchored in the research commissioned.

Groups that obtained more funding from charities scored significantly lower on several types of societal output products than others. This observation can be explained by the funding conditions of charities. Although charities focus on specific diseases (e.g. cancer or heart diseases) in their project selection process, they mainly concentrate on the scientific quality of the proposal. Dutch charities do not explicitly take societal relevance and societal output into account when selecting research proposals.[16] Most probably, research funded by charities is intrinsically of social relevance since it targets a disease: societal impact is expected to emerge from the contribution to new knowledge about a specific disease.

Finally, the proportion of funding from all research councils together[17] is not related to societal output. However, when we only consider the number of grant applications to the ZonMw council a moderate positive correlation exists between the number of grants obtained and societal productivity. The more frequently research groups apply for funding and receive grants from ZonMw, the more societal output is produced. Interestingly, this council strongly emphasises the need for socially relevant research and uses societal orientation in their proposal assessment criteria. Our analysis suggests that this seems to be effective (Table 9). The opposite is the case for the other research councils[18] in our study: they do not assess the societal quality of proposals in an explicit way, with the expected result. In conclusion, assessment procedures of research funding agencies are potentially powerful incentives and have serious implications for the behaviour of biomedical and health scientists.

***3.5.2 Leadership experience.*** Research management and leadership activities such as internal communication

**Table 10.** Societal productivity by leadership experience and group size†

| | | Leadership experience | Group size |
|---|---|---|---|
| Presentations to non-scientific public | Spearman's rho | −0.203** | −0.408*** |
| | *N* | 113 | 116 |
| Contributions to public media | Spearman's rho | −0.252** | −0.203** |
| | *N* | 101 | 104 |
| Education/courses for professionals | Spearman's rho | −0.394*** | −0.307*** |
| | *N* | 84 | 86 |
| Membership of committees developing guidelines/policies | Spearman's rho | −0.421*** | −0.396*** |
| | *N* | 86 | 89 |
| Contributions to conferences directed to stakeholders | Spearman's rho | −0.217** | −0.375*** |
| | *N* | 87 | 88 |
| Professional publications | Spearman's rho | −0.273** | |
| | *N* | 85 | |
| Clinical guidelines | Spearman's rho | | −0.522*** |
| | *N* | | 75 |
| Policy reports | Spearman's rho | −0.379*** | −0.527*** |
| | *N* | 48 | 49 |
| Editorship of societal-oriented journals | Spearman's rho | | −0.482*** |
| | *N* | | 48 |
| Membership of committees funding societal-oriented research | Spearman's rho | | −0.357** |
| | *N* | | 41 |

†The mentioned type of societal output (units per FTE) by leadership experience (in years) and group size (FTE)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

and rewarding structure are positively correlated with scholarly performance (Van der Weijden 2007; Van der Weijden et al. 2008). However, the way in which research leaders manage their groups did not seem to relate to the societal output of research groups. Nevertheless, experience in leadership and management is related to the societal output of research leaders. Groups that have more experienced research leaders produce less societal research output, such as contributions to public media, presentations for a non-scientific public, policy reports, professional publications, contributions to non-scholarly conferences, education of professionals and memberships of committees developing clinical guidelines and policy recommendations (see Table 10). This suggests that the younger generation of principal investigators is more aware of the increased societal demand for relevance.

***3.5.3 Group size.*** Group size also correlates negatively with societal productivity (see Table 10). For example, smaller groups developed more clinical guidelines, produced more policy reports and gave more presentations to non-scientific audiences per group member. Furthermore, research leaders of smaller groups were more often editors of professional journals as well as members of committees for developing guidelines, policy recommendations and funding societal-oriented research. Why this is the case needs further exploration. Are research leaders who focus on societal output less interested in acquiring research money for building up a large group? Or are research leaders inclined to reduce their societal activities, when the research group grows in size and an increasing amount of time is needed to manage it?

***3.5.4 Work environment.*** University-based groups were more active in realising various types of societal output than non-university groups. In comparison with non-university groups, a significantly higher percentage of the university-based groups gave presentations to a non-scientific public, contributed to the public media, participated in committees for developing guidelines or policy recommendations, contributed to stakeholder conferences, realised professional publications and developed clinical guidelines.[19] Principal investigators working in universities also had more positive opinions about: (1) societal goals (i.e. adaptation to medical problems in society and useful practical innovations); (2) interactions with societal stakeholders (i.e. patient organisations and policy makers); and (3) knowledge dissemination (i.e. knowledge exchange, products and use), than their colleagues at public research institutes.[20]

***3.5.5 Translational research.*** Finally, one of the manifestations of the increased focus on societal impact is the emergence of translational medical science: research that aims to translate fundamental knowledge into applicable treatments. That is, research that moves from bench to bedside. Increasingly, biomedical research is organised in this way. Using pre-clinical research groups (bench) that spend time on patient care (bedside) as indicators of translational medical science, we found that pre-clinical 'translational research' groups[21] are more active in generating societal output than those that do not spend time on patient care.

This exploratory study provides answers to our five research questions, as it gives a first impression of the views and activities of Dutch biomedical researchers with respect to societal orientation. Two limitations should be mentioned here: first, the results were collected in a one-shot study, and so our results cannot be compared over time; and secondly, the sample size creates restrictions for a more in-depth analysis.

## 4. Conclusions and discussion

We have demonstrated that, on average, principal investigators have a slightly positive attitude towards the increased emphasis that policy makers and research managers put on the societal impact of research. Their societal orientation is expressed in societal goals, communication with stakeholders and the dissemination of knowledge to stakeholders. A positive view towards societal orientation leads to more activity in order to realise societal output. Biomedical and health research groups produce a broad range of societal outputs. Principal investigators are not used to reporting the amount of societal output, which is not surprising, since the measurement of societal output is not implemented in research evaluation system in the same way scientific output is.

The three disciplines that we distinguished between differ in their societal orientation and societal output. Para-clinical groups are most active and productive in generating societal output, followed by clinical groups. Pre-clinical groups are least active and productive and they also have somewhat more neutral views towards societal orientation. Yet, pre-clinical research—as shown for the virology case—is oriented toward, and relevant for, clinical studies, and consequently, for clinical practice. In other words, pre-clinical groups seem to disseminate new knowledge to stakeholders via scholarly output. It seems that pre-clinical groups express their societal orientation indirectly at the research field level instead of directly via measurable societal output on a group level. Only when pre-clinical groups spend time on patient care, i.e. do translational research, are they more active in generating societal output. Apparently, translational research stimulates a broader societal orientation.

In our case we found that scientific and societal productivity are independent. Groups exist that have both high scientific and high societal productivity, groups that have both low scientific and low societal productivity, and groups that have high (or low) scientific productivity and low (or high) societal productivity. An orientation towards the wider socio-economic benefits of research is thus certainly not a residual task for researchers 'who are not good enough for an academic career' (Royal Society 2006). However, some types of societal output correlate moderately negatively with scholarly impact, while others do not. This suggests that specific efforts are required to stimulate societal research output, and that societal impact is not simply the consequence of policies which stimulate high scientific quality.

What could these specific policies look like? Our study found several managerial and organisational characteristics that relate to societal output and this leads to some policy implications. The relationship between the type of funding and societal output is mixed, which might be a result of the assessment procedures used by research funding agencies. Institutional funding correlates positively with societal productivity. In contrast, charity funding correlates negatively with societal productivity. This could be a result of their project selection criteria, since charities mainly focus on the scientific quality of proposals. Perhaps charities perceive the creation of new knowledge about a specific disease as socially relevant, and they might disseminate this new knowledge to a wider society themselves rather than leave this as a task for the researchers. No relationship was found with funding from industry and ministries. Actually, it is conceivable that the research commissioned by these stakeholders already has a societal or economic goal. Therefore, funding received from industry and ministries can be considered to be a type of societal output. Finally, funding from research councils—received in competitions—does not correlate with societal output. Not surprisingly, because they do not assess the societal quality of proposals. However, this seems different for the ZonMw which explicitly stimulates societal relevance in its selection procedures. Here we found that research groups that apply more often for grants and receive more grants from this council, are also generating more societal output. In conclusion, making societal relevance a condition for research funding would create a vigorous incentive, as this seems to influence the behaviour of research leaders.

Principal investigators with less leadership experience are more productive in realising societal output. This could be a generational effect. The increasing need to demonstrate socio-economic benefits from investments in research affects the strategies of research groups. The younger generation of research leaders may adapt to this with more ease than the older generation (Verbree et al. in press). However, we are aware that a longitudinal (panel) study is needed to verify statements about generational differences and the effects of experience. We plan to do this in the future. We also found a negative relationship between group size and societal output, suggesting that there is a trade-off between societal orientation and trying to create a large research group. This merits further investigation. Finally, the effect of a work environment on societal orientation calls for further research. Do university-based research groups have a stronger societal orientation than other research groups, because universities stimulate this?

Overall, our study shows a relatively strong orientation to societal relevance within the Dutch biomedical and health research fields, and this reflects the changing contract between science and society. However, we do realise that the connections between science and practice might be easier to make in the medical sciences than in other academic fields, such as physics or other natural sciences. Therefore it would be interesting to also study societal orientation in other academic scientific domains, which would allow us to compare results between disciplines. As Dutch biomedical and health research is internationally at the top of the discipline (NOWT 2010), we consider these results to be more generally relevant. Whereas in the past, society funded research with the expectation that societal pay-off would come at a certain point, nowadays society increasingly expects the inclusion of social benefits in research programming and in research from the outset. The younger generation of researchers takes up this challenge more explicitly than the older generation. This indicates a change in the science system in this respect: the new generation of principal investigators adapts its attitude in response to the changing science–society relationship (Verbree et al. in press). This adaptation of research leaders to the changing science–society relationship can potentially be reinforced by implementing incentives in funding allocation processes.

However, the incentives for focusing on societal impact are still weak within the science system, as research evaluation systems have only recently started to include societal impact as one of their criteria. The process of knowledge transfer to society may be improved considerably by supporting the societal orientation of research leaders in a more explicit manner (De Jong et al. 2011). The current incentive structure in the science system, including research careers, still seems largely based on scientific performance in a narrow sense. It has been pointed out that ties to society and political bodies do not lead to pay-offs that can be mapped by the conventional indicators of successful scientific performance, including contract funding (Atkinson-Grosjean and Douglas 2010; Krücken et al. 2009; Göransson et al. 2009; Hessels 2010). Universities, for example, like to exhibit their societal engagement, but, in practice, these activities remain largely unrewarded. Financial rewards may be an instrument for stimulating the broader impact of university research (Hessels and van Lente 2010). A study by a German university (Krücken et al. 2009) showed that societal output activities were all dependent on the personal motivation, voluntary commitment and informal, pre-existing personal ties of academic scientists. In addition, Jensen et al. (2008) showed that dissemination activities of French scientists have almost no (positive or negative) impact on their scientific careers. We expect a reduction in tensions between organisational goals and individual goals once societal activities are no longer valued as 'leisure time activities', and instead play a role in evaluating performance. This may help to solve the problem that junior scientists are rarely active in generating societal output (Göransson et al. 2009). Scientists should engage in a two-way dialogue with stakeholders at an early stage in their careers (Winston 2009). This idea is supported in the medical field.[22] Incentives aiming to intensify collaborations between academia and societal practitioners are a main factor for accomplishing socially relevant knowledge (De Jong et al. 2011; Knights and Scarbrough 2010). In conclusion, universities and research institutes now have a duty to evaluate both scientific and socially relevant output (Jensen et al. 2008). As a consequence, scientists should also be rewarded when they are active in producing socially relevant output.

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## Notes

1. In this study research group leaders are defined as principal investigators. The research group is the smallest unit at the micro-level of knowledge production.
2. Translational research is a contested term. Some use it for research that goes from the lab to clinical application, some for research that goes from clinical application to large-scale use. We use it for the whole trajectory.
3. A study of the Netherlands Institute for Health Promotion (NIGZ) and the Netherlands Organization for Applied Scientific Research (TNO) showed that Dutch policy makers view scientific information as not directly applicable and relevant to making contributions in the policy-making process (Keijsers et al. 2005).
4. The Netherlands Organisation for Health Research and Development.
5. Information on the ERiC project is available at <http://www.eric-project.nl>, accessed 20 March 2012. The related EU-funded SIAMPI project has

similar aims. Information about it is available at <http://www.siampi.eu>, accessed 20 March 2012.

6. This process can go both ways. Observations made in the clinic during the treatment of patients may feed back to inform basic research questions which seek to understand the effects seen in the clinical therapies. In this paper we primarily focus on the flow from basic research towards application.
7. Scholarly performance is defined here as the number of publications over a three-year period (2004–6). Thomson Reuters (formerly ISI) Web of Knowledge and PubMed (US National Library of Medicine's search service) were used as data sources.
8. Mann–Whitney tests with a Bonferroni correction show that leaders of pre-clinical groups differ significantly (with a level of significance at 0.10) from para-clinical leaders in their attitude towards taking societal needs into account, adapting to medical problems within society, contributing to useful practical innovations from clinical leaders, and in their attitude towards taking societal needs into account.
9. Mann–Whitney tests with a Bonferroni correction show that leaders of pre-clinical groups differ significantly (with a level of significance at 0.10) in their attitude towards interactions with stakeholders from para-clinical leaders (viz. professionals in prevention and care and policy makers) and clinical leaders (viz. policy makers and patient organisations).
10. Mann–Whitney tests with a Bonferroni correction show that leaders of pre-clinical groups differ significantly (with a level of significance at 0.10) in their attitude towards knowledge dissemination from leaders of para-clinical and clinical leaders.
11. This is not always the case. Ethical issues are often involved in pre-clinical research.
12. This was calculated with point biserial correlations between activity in societal output (yes or no) and views about societal research goals, interaction with stakeholders, and knowledge dissemination to stakeholders.
13. Pearson's chi-square statistics show that para-clinical research groups were significantly more active in the mentioned societal output categories, and that pre-clinical research groups were significantly less active in the mentioned societal output categories, with a level of significance at 0.05. Mann–Whitney tests with a Bonferroni correction show that para-clinical groups differ significantly in productivity of the mentioned societal output products, and that pre-clinical research groups differ significantly in productivity of the mentioned societal output products, with a level of significance at 0.05.
14. The questions were posed dichotomously (yes or no). These types of societal output were not included in our study.
15. In our study, the entrepreneurial activities and commercial performance of research groups, such as the identification and measurement of scientist-invented patents were not taken into account. This will be included in future research.
16. We verified their grant selection procedures on the websites of three large charity funds in the Netherlands, i.e., de Nederlandse Hartstichting (<www.hartstichting.nl/research>, accessed 20 March 2012) (Dutch Heart Foundation); de Maag Lever Darm Stichting (<http://www.mlds.nl/>, accessed 20 March 2012) (Dutch Digestive Foundation), and KWF Kankerbestrijding (<www.kwfkankerbestrijding.nl>, accessed 20 March 2012) (Dutch Cancer Society). We also verified the grant selection procedures at the research councils in the Netherlands.
17. Research councils in the Netherlands: NWO is the Dutch Research Council; ZonMw is the Dutch Research Council for Medical Science; KNAW is the Royal Netherlands Academy of Arts and Sciences.
18. The other research councils refer to NWO and KNAW (see also Note 15).
19. Pearson's chi-square statistics show that university-based groups were significantly more active in generating various societal output than non-university groups. No significant differences were found for policy reports, education or courses for professionals, editorship of societal-oriented biomedical and health journals, and committee membership for funding societal-oriented biomedical and health research.
20. Mann–Whitney tests show significant differences between university-based groups and non-university groups in societal orientation, with a level of significance at 0.05.
21. Pearson's chi-square statistics show that a higher percentage of pre-clinical research groups that spent time on patient care generated societal output compared to pre-clinical research groups that did not spend time on patient care. Specifically, there was a significant association between patient care and realising presentations to non-scientific public (89.2% vs. 66.7%, $p < 0.05$), contributions to media (81.1% vs. 52.4%, $p < 0.01$), education/courses for professionals (70.3% vs. 50.0%, $p < 0.10$), guidelines/policy recommendations (81.1% vs. 26.2%, $p < 0.001$), contributions to conferences for stakeholders (62.2% vs. 40.5%, $p < 0.10$), professional publications (59.5% vs. 35.7%, $p < 0.05$), clinical guidelines (75.7% vs. 7.1%, $p < 0.001$) and policy reports (43.2% vs. 9.5%, $p < 0.01$).
22. We presented our research to 72 biomedical and health research leaders in the Netherlands who are working in three different UMCs. 71% shared the opinion that scientists should be stimulated to think about the

possible societal impact of their research projects at a very early phase in their academic careers.

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## Appendix

**Table A1.** Descriptive statistics of opinions of research leaders on societal research goals

| | | N | Median | Bottom quartile | Top quartile | Mean | SD |
|---|---|---|---|---|---|---|---|
| Research in my group takes societal needs into account | *Para-clinical* | 25 | 4.00 | 4.00 | 4.00 | 3.80 | 0.957 |
| | *Pre-clinical* | 78 | 4.00 | 3.00 | 4.00 | 3.42 | 0.933 |
| | *Clinical* | 80 | 4.00 | 3.00 | 4.00 | 3.76 | 0.945 |
| Research in my group is adapted to medical problems within society | *Para-clinical* | 25 | 4.00 | 3.00 | 4.00 | 3.64 | 1.036 |
| | *Pre-clinical* | 78 | 4.00 | 3.00 | 4.00 | 3.42 | 0.974 |
| | *Clinical* | 80 | 4.00 | 3.00 | 5.00 | 3.83 | 1.063 |
| Research in my group results in useful practical innovations | *Para-clinical* | 25 | 4.00 | 3.00 | 4.50 | 3.64 | 1.114 |
| | *Pre-clinical* | 78 | 4.00 | 3.00 | 4.00 | 3.40 | 1.024 |
| | *Clinical* | 80 | 4.00 | 3.00 | 4.00 | 3.79 | 0.910 |

Five-point scale with 1 is 'totally disagree', 3 is 'not disagree, not agree', 5 is 'totally agree'

**Table A2.** Descriptive statistics of opinions of research leaders of increased interactions with stakeholders

| | | N | Median | Bottom quartile | Top quartile | Mean | SD |
|---|---|---|---|---|---|---|---|
| Professionals in prevention and care | *Para-clinical* | 25 | 4.00 | 3.00 | 4.50 | 3.76 | 1.012 |
| | *Pre-clinical* | 77 | 3.00 | 3.00 | 4.00 | 3.36 | 0.842 |
| | *Clinical* | 80 | 4.00 | 3.00 | 4.00 | 3.58 | 0.897 |
| Policy makers | *Para-clinical* | 25 | 4.00 | 3.00 | 4.00 | 3.64 | 1.036 |
| | *Pre-clinical* | 77 | 3.00 | 3.00 | 4.00 | 3.12 | 0.827 |
| | *Clinical* | 80 | 4.00 | 3.00 | 4.00 | 3.53 | 0.900 |
| General public | *Para-clinical* | 24 | 4.00 | 2.25 | 4.00 | 3.42 | 1.018 |
| | *Pre-clinical* | 78 | 3.00 | 3.00 | 4.00 | 3.19 | 0.913 |
| | *Clinical* | 80 | 4.00 | 3.00 | 4.00 | 3.45 | 0.013 |
| Patient organisations | *Para-clinical* | 25 | 3.00 | 3.00 | 4.00 | 3.44 | 1.121 |
| | *Pre-clinical* | 78 | 3.00 | 2.75 | 4.00 | 3.12 | 0.882 |
| | *Clinical* | 80 | 4.00 | 3.00 | 4.00 | 3.43 | 0.911 |
| Industry | *Para-clinical* | 25 | 3.00 | 2.00 | 4.00 | 2.92 | 1.152 |
| | *Pre-clinical* | 77 | 3.00 | 2.00 | 4.00 | 3.10 | 0.882 |
| | *Clinical* | 80 | 3.00 | 2.25 | 4.00 | 3.20 | 1.060 |

Five-point scale with 1 is ‘totally disagree’, 3 is ‘not disagree, not agree’, 5 is ’totally agree’

**Table A3.** Descriptive statistics of opinions of research leaders of increased knowledge dissemination to stakeholders

| | | n | Median | Bottom quartile | Top quartile | Mean | SD |
|---|---|---|---|---|---|---|---|
| Knowledge exchange | *Para-clinical* | 25 | 4.00 | 3.00 | 4.00 | 3.76 | 0.879 |
| | *Pre-clinical* | 75 | 3.00 | 3.00 | 4.00 | 3.20 | 0.900 |
| | *Clinical* | 78 | 4.00 | 3.00 | 4.00 | 3.54 | 0.863 |
| Knowledge products | *Para-clinical* | 25 | 4.00 | 3.00 | 4.00 | 3.56 | 1.003 |
| | *Pre-clinical* | 74 | 3.00 | 2.00 | 4.00 | 3.00 | 0.979 |
| | *Clinical* | 78 | 3.00 | 3.00 | 4.00 | 3.32 | 0.987 |
| Knowledge use | *Para-clinical* | 25 | 3.00 | 3.00 | 4.00 | 3.36 | 0.757 |
| | *Pre-clinical* | 75 | 3.00 | 2.00 | 4.00 | 2.99 | 0.951 |
| | *Clinical* | 78 | 3.00 | 3.00 | 4.00 | 3.37 | 0.839 |

Note: five-point scale with 1 is ‘totally disagree’, 3 is ‘not disagree, not agree’, 5 is ’totally agree’